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Trends and Patterns of Built-Up Expansion in the NCT of Delhi

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ABSTRACT: Developmental processes have altered the landscape of NCT of Delhi through the widespread expansion of built-up and the decline in vegetation cover. The land use and land cover of the NCT of Delhi is dominated by the built-up as compared to the vegetation cover. This built-up expansion took place at the cost of agricultural/cultivable land. The present research study attempts to analyze the spatial and multi-temporal expansion in built-up by using Geographical Remote Sensing (GIS) and Remote Sensing. The present research study is based on the remote sensing data of Landsat-7 (TM), Landsat-7 (ETM+) and IRS-P6 LISS III of 1987, 1999 and 2006 respectively. The data interpretation and analysis of built-up expansion in the NCT of Delhi helps in understanding the changes in land cover, causes of built-up expansion and impact of built-up expansion on micro-climate.

Keywords: Built-Up, Grey Infrastructure, Developmental Processes, Micro-Climate Changes.

1. Introduction

Multi-storey buildings (both commercial and residential), Malls, Real Estate Township, Multi-level Parking, broad roads, fly overs, metro rail have become the major and dominant part of the present landscape of the NCT of Delhi. Consequently, the urban environment of the NCT of Delhi is dominated by the built-up with reduced 'Urban Open Spaces' and this Built-up expansion took place at the cost of agriculture/cultivable land, forest land. The expansion in the built-up and reduction in vegetation cover has resulted in micro-climatic changes like Urban Heat Island effect and the intensification of Heat waves during the summer season. Further, there is growing socio-economic disparity (epidemic breakouts, social disparity, informal economy). Hence, the urban environment in the NCT of Delhi is under the severe stress due to the pressure of rapid urbanization. Consequently, urbanization has deteriorated the overall quality of the urban environment in the NCT of Delhi. The present research study is focused to identify the built-up expansion and its impact on social and economic life of urban dwellers in the NCT of Delhi.

2. Objectives of the Study

The objectives of present research study area as follows:

- To critically analyze the trends and patterns of built-up expansion during 1987-2006 in the NCT of Delhi.
- To examine the loss of forest cover and agricultural/cultivable area during 1987-2006 in the NCT of Delhi.

3. Methodology

The land use and land cover of the NCT of Delhi was carried out from satellite data of Landsat – 7 (TM), Landsat – 7 (ETM+) and IRS – P6 LISS III for the three different time periods 1987, 1999 and 2006.

3.1 Data Source

The satellite imageries of the NCT of Delhi for three different periods that is 1987, 1999, 2006 were obtained from the following sources:

- Global Land Cover Facility (GLCF).
- NRSA, Hyderabad, India.

3.2 Tools of Analysis

- To carry out the Geometric correction of the image:

$X = f_1(X, Y)$ $y = f_2(X, Y)$

Where,

(x, y) = distorted-image co-ordinates (column, row)
(X, Y) = correct (map) co-ordinates
f_1, f_2 = transformation function

- To carry out the Radiometric correction of the image:

$$E = \frac{E\emptyset \; Cos \; q\emptyset}{d}$$

Where,

E = normalized solar irradiance
EØ = solar irradiance at mean earth-sun distance
qØ = sun's angle from the zenith
d = earth-sun distance (astronomical units)

- To calculate the 'Rate of Change Per Year', we will use the following formula (Chebet, C. 2013):

$$R = \frac{Y - X}{T}$$

Where,
R = rate of change.
Y = the area (km^2) of the study area in the final year.
X = the area (km^2) of the study area in the initial year.
T = the time difference in years

3.3 Software and Platforms

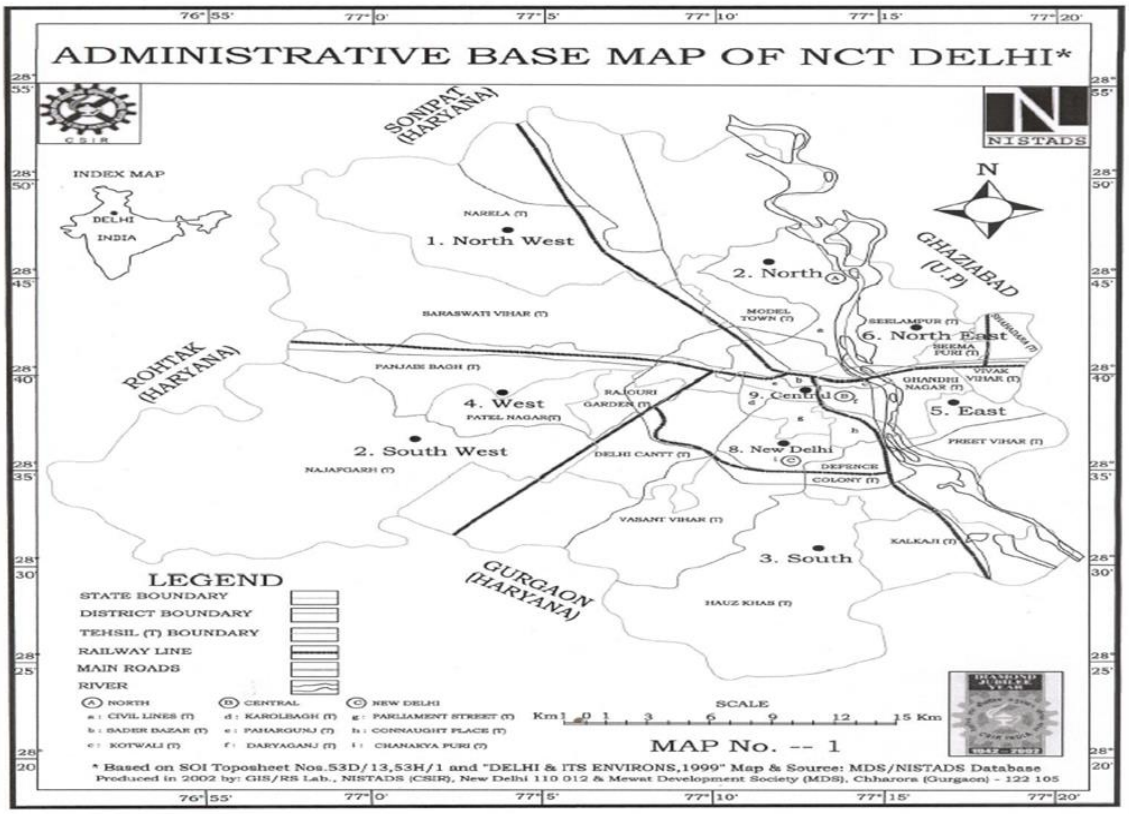
The following software and platforms are involved in the present research study:

- ERDAS Imagine ver. 9.1
- ArcGIS ver. 9.1

4. Study Area

The present research study has been carried out on the NCT of Delhi, the capital city of India located between the 28° 24′17″ N to 28° 53′00″ N latitudes and 76° 45′30″ E to 72° 21′30″ E longitudes. The NCT of Delhi is situated near the western bank of river Yamuna which spreads over an area of around 1,483 km2 is surrounded by the Himalayas in the North and the Aravalli in the South-west (Figure 1). The hottest months are May and June with temperatures touching 48°C, whereas, the lowest falls to about 5°C at the end of December-January. The monsoon season lasts from July to September with maximum rainfall in the month of July to September with maximum rainfall in the month of July (around 300 mm). The total population of Delhi was nearly 0.4 million in 1901, which increased slowly and reached 1.74 million in 1951 (4.35 times in Century) and reached 13.78 million in 2001 implying about 34.45 times increase in one century.

Figure 1
Location Map of Study Area, NCT of Delhi, India



5. Built-Up Expansion During the Period 1987-2006

Built-up is defined as an area of human habitation developed due to non-agricultural lands which covers the buildings, industrial structures, transportation network etc. a simple superimposing technique was used to assess the spatial growth of built-up area for the given period of 19 years (Figure 2). All the three-land use and land cover maps of the NCT of Delhi are predominantly covered with built-up area. The map is extracted in

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tabular form, the built-up area is predominantly covered with 25% of the total area of Delhi-NCT.

Figure 2
Land Use and Land Cover Maps (1977-2012), NCT of Delhi, India

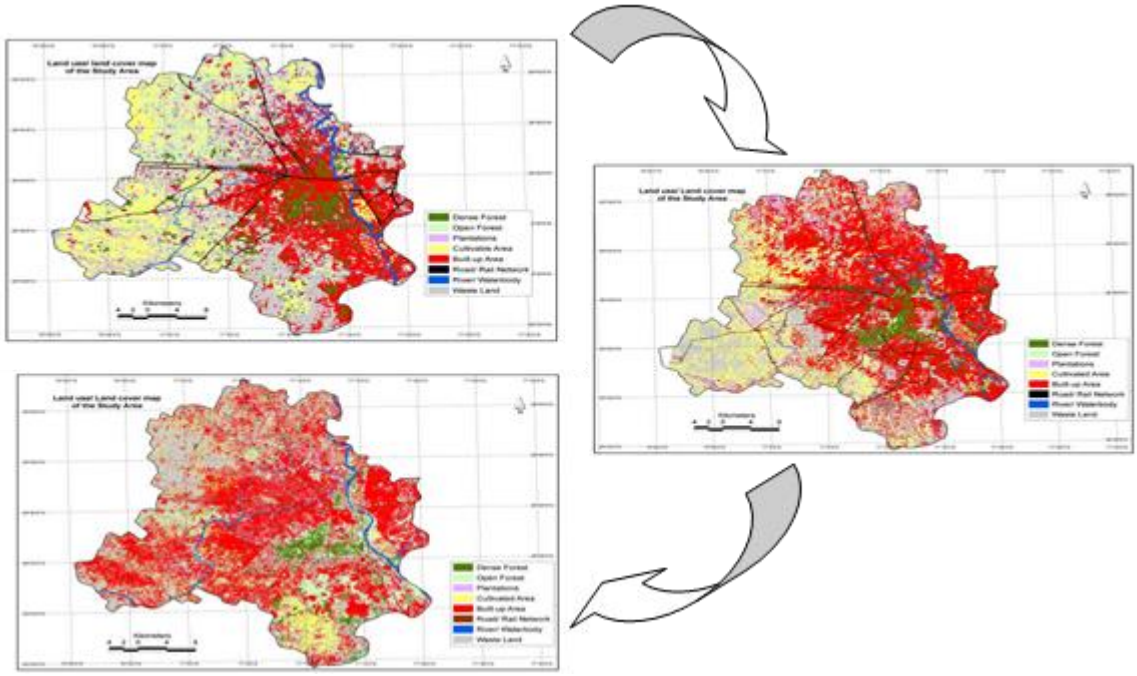

Table 1
Area under Different Land Use and Land Cover Changes, 1987-2006, NCT of Delhi, India

Land Use/Land Cover Categories	1987 Area (ha)	%age	1999 Area (ha)	%age	2006 Area (ha)	%age
Dense Forest	7622.62	5.14	9960.34	6.74	5768.87	3.89
Open Forest	26174.95	17.65	16329.70	11.05	16718.24	11.27
Plantations	12486.86	8.42	11556.40	7.82	7835.07	5.28
Cultivable Area	25018.21	16.87	19684.31	13.32	14503.74	9.78
Built-Up Area	37045.34	24.98	60959.29	41.25	63146.14	42.58
Road/Rail Network	3618.52	2.44	2113.26	1.43	7261.53	4.90
River/Waterbody	6169.28	4.16	2438.37	1.65	2254.16	1.52
Waste Land	30164.22	20.34	24738.39	16.74	30816.74	20.78
Total	***148304.49***		**147780.06**		**148300.00**	

Source: Compiled by Author and Calculated from Satellite Images

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Expansion in Urban Built-Up Area During 1987-2006, NCT of Delhi, India

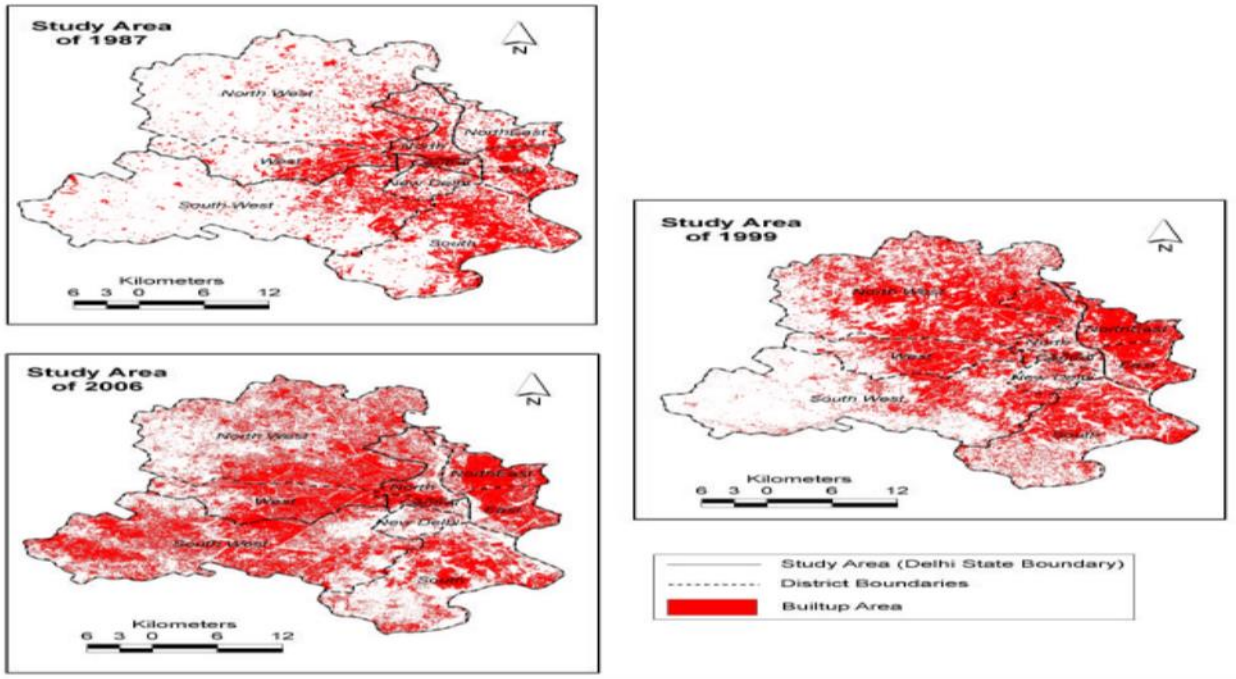
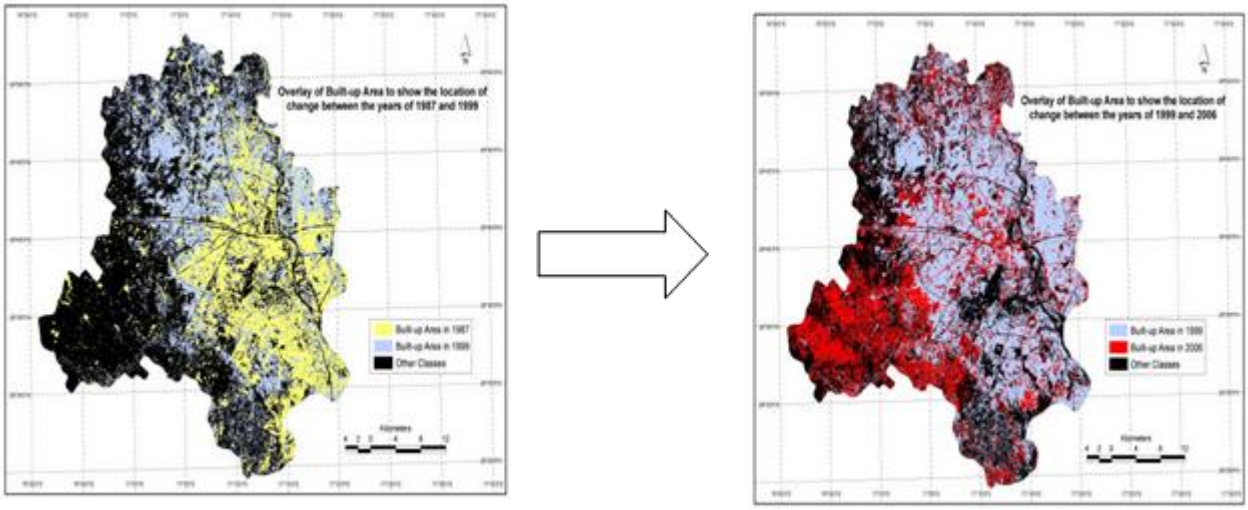


Figure 4
Overlay of Built-Up to show the location of change between the years 1987-1999 and 1999-2006



The careful observation of the land use/land cover map of 1987 of the NCT of Delhi shows that urban built-up is majorly concentrated in the north-eastern part, eastern part, south- eastern part (Figure 2). On the other hand, northern, north-western, western, south-western and southern part is dominated by the cultivable land area. Though, the wasteland can be observed throughout the map but major part is in southern part of the NCT of Delhi. The other categories like road/rail network and river/waterbody are not having much role to play.

The land use/land cover map of 1999 of the NCT of Delhi shows that the urban built-up experienced the westward expansion with maximum growth in northern part and comparatively, less growth in southern part. The urban- built has increased at a tremendous rate and such increase can be attributed to the fact like rapid increase in population, rapid pace of urbanization. Except some patches in north-western, western and major part in south-western which were under the cultivable land area along with the presence of waste land in the south-western part of the NCT of Delhi (Figure 2). the dark green patch representing Dense forest has

increased in south-eastern part of the NCT of Delhi and there is complete absence of green patches or dense forest in the northern, western and southern part of the NCT of Delhi.

The urban built-up covers almost the whole of the NCT of Delhi except the southern-most part (under cultivable land) and the central eastern part (under the dense forest). The core of the NCT of Delhi is characterized by the dense network of urban built-up while the density of urban built-up decrease towards periphery. Further, density of the green patch representing dense forest also decreased in Central eastern part of the NCT of Delhi (Figure 2). Further, the map shows presence of cultivable land in the southern part of NCT of Delhi. this southern part was earlier under the urban built-up category.

During 1999, built-up area had increased to 41%, with sharp decrease in open forest, wasteland and agricultural land areas. Between the year 1999 and 2006, there was slight increase in built-up class with only 1% increase i.e. 42% of the total administrative area of the NCT of Delhi comprised built-up space. Over the period of 19 years, built-up area had increased to 18% in the NCT of Delhi. However, when the two Land use/land cover maps of 1999 and 2006 were compared, one can observe the marked difference in the western part of the NCT of Delhi (Figure 3 and Table 1).

6. 'Rate of Change' of Built-Up During 1987-2006

The Table 2 contains the calculated data of 'Rate of Change' of land use/land cover for the period 1987-2006 in the NCT of Delhi. During the period of 19 years, built-up area shows the positive rate of change and attains the highest value of +1374 (Table 2) among all categories of land use/land cover in the NCT of Delhi. The other categories which experienced an increase in land use/land cover include road/rail network (+191) waste land (+34). On the other hand, Forest and cultivable area shows the negative rate of change of -595 and -553 respectively. The negative change in the forest land and the cultivable land shows that these two categories of land use/land cover experienced the loss of land and this loss of land took place due to the developmental activities involved in built-up area and road/rail network. The other categories which face negative growth of land includes Plantation and river/waterbody with rate of change -245 and -206 respectively.

Table 2

'Rate of Change' of Land Use/Land Cover, 1987-2006, NCT of Delhi, India

Sl.No.	Land Use/Land Cover	1987-1999 Area (ha)	1999-2006 Area (ha)	1987-2006 Area (ha)	$R = \frac{Y - X}{T}$
1	Forest	-7507.53	-3802.93	-11310.46	-595.29 ~ -595
2	Plantations	-930.46	-3721.33	-4651.79	-244.83 ~ -245
3	Cultivable Area	-5333.90	-5180.57	-10514.47	-553.39 ~ -553
4	Built-up Area	+23913.95	+2186.85	+26100.80	+1373.72 ~ +1374
5	Road/Rail Network	-1505.26	+5142.27	+3643.01	+191.42 ~ +191
6	River/Waterbody	-3730.91	-184.21	-3915.12	-206.05 ~ - 206
7	Waste Land	-5425.83	+6078.35	+652.52	+34.34 ~ +34

Source: Calculated and Compiled by the Author

Note: Positive sign (+) indicates an increase while the Negative sign (-) indicates decrease in area.

Figure 5

Rate of Change of Different Land Use Categories During 1987-2006 in the NCT of Delhi

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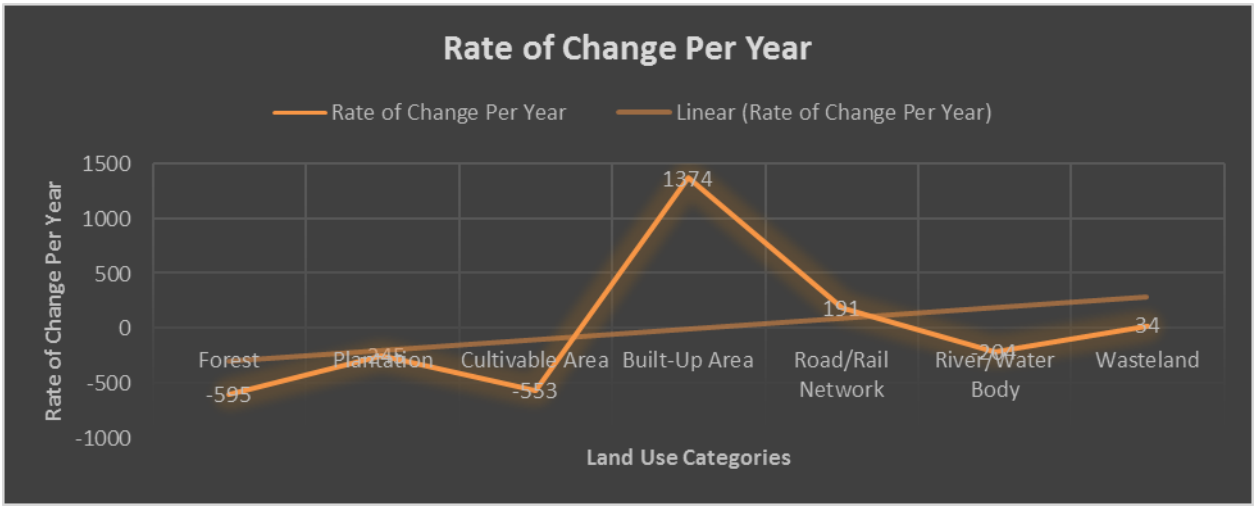

7. Loss of Vegetation Cover and Forest Cover During 1987-2006

The changes in the Land Use/Land Cover in the study area were estimated from 1987-2006.

7.1 Forest

The area of crops rose in the forest and grazing lands or areas open for grazing within the forests should remain included under the forest area. It is an area notified for forestry boundary, predominantly with trees and other vegetation capable of producing either timber and other forest produce. Approximately, 11,000 ha. of forest lands (Open forest and Dense forest) were lost during the study period. Moreover, the NCT of Delhi is covered with open forest rather than the dense forest, therefore, conversion of open forest to other land uses was more prevalent. The land area under the dense forest increased from 5.14% (1987) to 6.74% (1999) but in the year 2006, the land area under the dense forest decreased to 3.89% (Table3, Table 4 & Table 5). The discussion over the land use/land cover change shows that there was an increase of 2337.72 ha. of land under the category of dense forest during the year 1999 but the increased demand of land for grey infrastructure resulted in the loss of 4191.47 ha. land. Open forest being more vulnerable experienced large scale of decrease from 17.65% (1987) to 11.05% (1999) with slight increase of 0.22% in the year 2006.

7.2 Agricultural Land

It is defined as the land primarily used for farming and production of food crops, commercial crops and horticulture crops. It includes the land under irrigation and rain-fed crops, which are growing under different season in different farming activities. During 19 years, an area of around 10,000 ha. of agricultural lands was lost to built-up areas and road infrastructure. These agricultural lands were prominently spread in the north-western and western part of the NCT of Delhi up to 1987. The agricultural land in the NCT of Delhi have declined considerably during the study period. The agricultural land decreased to 13.32% (1999) from 16.87% (1987) and in the year 2006, the land area under agriculture was reduced to the 9.78% (2006) from 13.32% (1999). Near about 5333.9 ha of land was lost during 1987-1999 & 5180.57 ha of land was lost during 1999-2006 (Table3, Table 4 & Table 5).

Table 3
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1987-99, NCT of Delhi, India

Land Use Categories	1987 Area	%Age	1999 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	33797.57	22.79	26290.04	17.79	-7507.53	-5.00
Cultivated Area	25018.21	16.87	19684.31	13.32	-5333.90	-3.55

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area.

Table 4
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1987-99, NCT of Delhi, India

Land Use Categories	1999 Area	%Age	2006 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	26290.04	17.79	22487.11	15.16	-3802.93	-2.63
Cultivated Area	19684.31	13.32	14503.74	9.78	-5180.57	-3.54

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area.

Table 5
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1987-99, NCT of Delhi, India

Land Use Categories	1987 Area	%Age	2006 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	33797.57	22.79	22487.11	15.16	-11310.46	-7.63
Cultivated Area	25018.21	16.87	14503.74	9.78	-10514.47	-7.09

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area

8. Impact on Micro-Climate of NCT of Delhi

Over-expansion of grey infrastructure due to urbanization have induced micro-climatic changes in the form of Urban Heat Island (UHI) effect in the NCT of Delhi. The UHI effect results in thermal discomfort (both indoor and outdoor) and increased energy consumption in air conditioned buildings. It is estimated that 3% to 8% higher electricity demand in cities with populations greater than 1,00,000 is used to comfort the heat due to heat island effect.

The solar energy in the form of solar radiations falls on the surface of cultural features like buildings, roads. The part of this incoming solar radiation is reflected into space as solar reflectance of the surfaces due to reflectivity while the remaining part of solar radiation is absorbed and results in heating of cultural features and on heating, cultural features emit infra-red radiations due to emissivity. During this process, air temperature is increased due to absorption of solar radiation by the atmosphere and the heat emitted by different surfaces while surface temperature is increased due to solar radiation and the solar reflectance of the surfaces. Surface Temperature plays major role in the Urban Heat Island (UHI) effect because hot surfaces of the cultural features emit heat in the surroundings which in turn increases the air temperature and thus, making surroundings much warm as compared to the rural counterpart. Urban Heat Island (UHI) effect is the result of combination of several factors like more heat absorbing surfaces (Rooftops, Buildings and Paved Surfaces), the trapping of hot air between buildings, limited tree cover and other heat trapping and heat inducing factors such as fuel combustion and air conditioning, can result in average annual temperatures in urban areas being 1-3°C hotter than surrounding areas. This Urban Heat Island (UHI) effect is observed during night in the summer season in the NCT of Delhi. Urban Heat Island (UHI) effect intensifies the heatwaves during summer in the urban areas and consequently, residents are exposed to higher temperatures during day as well as night.

Conclusion

Built-up expansion has acquired every hook and corner of the NCT of Delhi with reduced number of 'Urban Open Spaces' and continuously decreasing vegetation cover. This built-up expansion has resulted in micro-climatic changes like Urban Heat Island effect, intensification of heatwave effectivity during summer season. Built-up expansion in the necessary and sufficient condition for the developmental process but micro-climatic changes needs to be considered. Provisions like green building rating system (GRIHA, LEED), green roofing, use of light shades of color for outer walls, roof top farming should be followed in order to minimize the impact of micro-climatic changes in the NCT of Delhi.

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